TASK 2
TECHNICAL WORK IN THE AREA
OF VIDEO TELECONFERENCING

SUBTASK 6

HIGH DEFINITION TELEVISION STANDARD
(HDTV)

FINAL REPORT

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1. OVERVIEW

The purpose of this document is to discuss the status and features of High Definition Television (HDTV) in the United States. HDTV is a new television standard which will replace the present NTSC standard as the governing standard for broadcast television transmission in the United States since early in the 1950s. The standard has been completed and was presented to the FCC on November 28, 1995.

HDTV provides many new and very desirable features for television transmission systems such as higher resolution pictures, higher frame rates, progressive scan, superior audio, ancillary data transmission, program guide, etc. The television signal, although containing these advanced features, can still be transmitted within a 6 MHZ channel (or digitally at 19.2 Mbps). The digital signal format permits using many of the new and developing digital storage techniques and transmission systems.

At the same time that the HDTV broadcast standard is being finalized in the U.S., a closely related international telecommunication standard [H.310] is nearing completion at the ITU [International Telecommunications Union]. The H.310 standard fully defines a telecommunication terminal capable of transmitting Standard Definition Television [SDTV] as well as HDTV signals over the Broadband ISDN network [transmission rates beyond the T1 channel]. Both the ITU H.310 Recommendation and the HDTV Grand Alliance specification are based on the ISO MPEG-2 standard. It is this common MPEG-2 heritage which insures that the U.S. HDTV signal can be transmitted over the forthcoming B-ISDN communication infrastructure. The simultaneous completion of these two standards has major implications for future audio visual communications within the Federal Government. The broadcast HDTV standard will drive the development of low cost HDTV cameras, monitors, tape recorders and related video infrastructure. These products, when combined with the H.310 standard, will make very high quality multimedia communications very cost effective.

The new HDTV standard has three key elements which differentiate it from the present NTSC standard. The most basic difference is the fundamental increase in resolution. In fact the HDTV standard provides for six different scanning formats including both interlaced and non-interlaced [progressive] modes. Interlaced operation permits transmission of the conventional TV signal structure, while the progressive modes provide for interoperability with other imaging formats, including those used in computer systems. The second major difference is that the transmission format is digital rather than analog. As explained above, the new format conforms to the international MPEG-2 standard to promote compatibility of the new U.S. system with others being developed throughout the world. The third major change is the audio system. Like the video, the new audio system is all digital. The new audio system incorporates the Dolby AC-3 technology which will provide CD-quality sound in the digital TV receiver.

Sections 2.0 and 3.0 provide the background and status of the HDTV standardization process. The technical characteristics of the HDTV system are described in sections 3.0 and 4.0. Section 6.0 provides on overview of ITU telecommunications standards which relate to HDTV. Finally sections 7.0 and 8.0 discuss the potential applications for HDTV in the Federal Government, conclusions, and recommendations. Section 9.0 contains a list of references describing the current status of HDTV and its various contributing technologies.

2. BACKGROUND OF HDTV STANDARDS IN THE UNITED STATES

2.1. History

The concept of high definition television has been talked about since at least the 1960s. The hardware technology for the mass production of high definition system components was not available, nor was there a commercial or public interest in high definition television. Black and white broadcast television was standardized in the 1940s, color was added in the 1950s, video tape players and video disks in the 1960s. Digitization of video was an expensive task. There were no standards so that each of the few HDTV or digital TV systems implemented required a customized design effort. In the early 1980s it became apparent that the technology in integrated circuits, compression techniques, digital transmission techniques, sensors and displays had matured to the point where HDTV of some sort was feasible. The impetus of the commercial home TV market, evaluated at well over $100 billion, stimulated activity in HDTV.

The following items are some of the major landmarks in the development of HDTV standards in the United States.

1982	Advanced Television System Committee (ATSC) was chartered with EIA, IEEE, NAB, NCTA, and SMPTE (Society of Motion Picture and Television Engineering) as charter members.
1984	First proposals for terrestrial HDTV broadcasting systems based on NTSC.
1986	Many additional HDTV system proposals began to appear.
2/87	The FCC was petitioned by broadcasting organizations to explore the impact of HDTV.
1987	The Japanese early HDTV MUSE-encoded TV system was demonstrated in Washington, D.C.
10/87	Advisory Committee on Advanced Television Service (ACATS) was established by the FCC to advise on the technical, economic, and public policies and standards and regulations for a new television transmission service.
10/88	SMPTE 240M was accepted by ANSI as the American national standard for studio production.
12/88	DARPA funded major HDTV development projects.

1989 Advanced Television Systems Committee defined terms related to HDTV.

3/90 FCC defined HDTV goals; a simulcast system, with the NTSC and HDTV signal each transmitted within a 6 MHZ channel.

5/90 The field of HDTV candidate systems was reduced to 6 HDTV proponents with 8 candidate techniques competing to be adopted as the HDTV standard. There were as many as 14 proponents with 23 techniques for advanced television systems which were eventually reduced to four.

5/90 First all-digital HDTV system proposed.

1990 The first DBS venture, Sky Channel, was formed by GM, Hughes Com, NBC, Cablevision, and News Corp., featuring 108 channels.

1992 ATSC assigned to document ATV (Advanced TeleVision) standards by the FCC.

3/93 The Digital HDTV Grand Alliance was formed. They had developed the four remaining ATV techniques. They refined these to a single best technique which was recommended to the ACATS.

4/95 ATSC completed and approved the HDTV standard for submission to ACATS.

8/95 ATSC completed the SDTV modifications to the HDTV standard.

9/95 The Grand Alliance prototype HDTV system is being field tested and compared to NTSC transmission.

11/28/95 The ATSC Digital Television Standard for HDTV Transmission was recommended to the FCC for approval.

Anticipated Near Future Activity

1996 Experimental HDTV broadcasting and HDTV system component development.

1997 Commercial HDTV broadcasting.

2.2. Standardization Process for Broadcast Television

The FCC has the authority to approve the broadcast television transmission standard for the United States. In 1951, it approved the National Television System Committee (NTSC) color television standard as the United States digital television system (13818-

1), video compression (MPEG-2)(13818-2), audio broadcast standard. Black and white television broadcast standards have existed since the earlier 1940s.

Similarly, the FCC is the agency authorized to approve the new High Definition Television Standard and replace the present NTSC standard with the Digital Television Standard for HDTV Transmission as the United States standard for broadcast television.

The preparation of an HDTV standard is a massive task. In 1987 the FCC appointed an Advisory Committee on Advanced Television Service (ACATS) to support and advise the FCC in the development of this standard. This committee has provided guidance to all organizations involved in the standardization process and has tested prototype units of proposed HDTV systems including the finally selected Grand Alliance system.

The Advanced Television Systems Committee (ATSC) was requested to document the broadcast HDTV standard to be forwarded to the FCC through the ACATS after their approval. In June 1992, the ATSC provided a plan of proposed industry actions to fully document the HDTV standard and identified industry groups which would provide the documentation information. These included the EIA, IEEE, NAB, NCTA, and the SMPTE. The ATSC completed and approved their HDTV standard in 1995. See Figure 2.1.

The Digital HDTV Grand Alliance is an organization composed of the three groups which had developed the four final digital contending HDTV techniques (a total of 7 participants). In May of 1993 they developed a single "best-of-the-best" system and withdrew their previous proposed systems. It is this system which is called the "Grand Alliance System" and has been tested by the ACATS and incorporates the requirements documented by the ATSC.

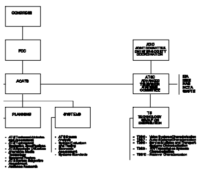
See below for the present status.

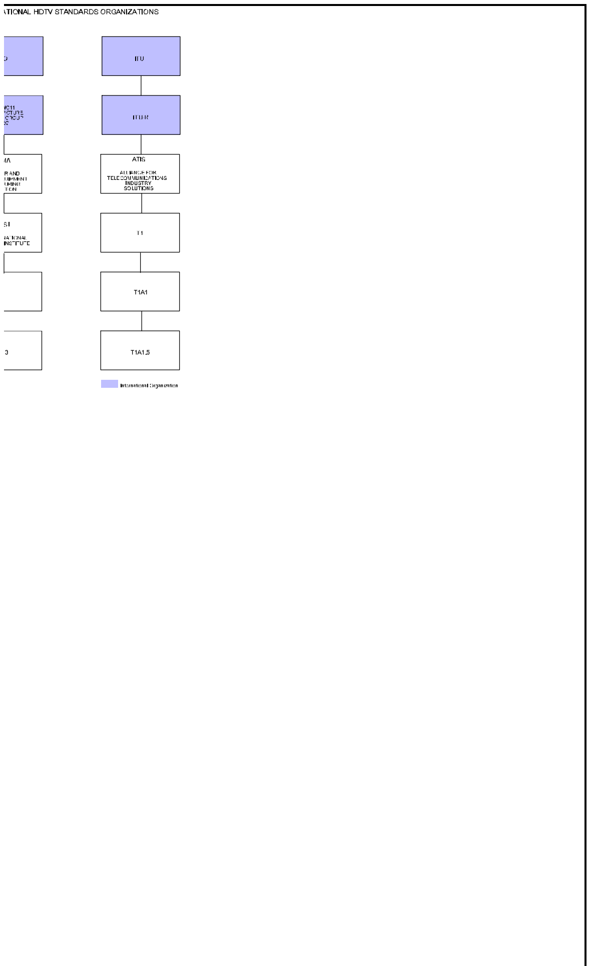
Coincidental with the HDTV effort in the United States, international technical organizations were also developing standards for international use of compressed digital television. Leading organizations are International Standards Organization and International Telecommunications Union. These organizations are shown in Figure 2.2. The United States is well represented in these technical organizations. The United States, besides independent development, drew on the work of these groups, incorporated the best of their concepts into the broadcast HDTV standard. An example is the utilization of the MPEG-2 video coding standard.

2.3. HDTV Telecommunications Standards

The heart of the digital television standards is the compression of moving pictures. The video compression technique is that developed by the Motion Picture Experts Group, a joint ISO/ITU group and is known as MPEG-2. This technology was

DOMESTIC STANDARDS ORGANIZATIONS ASSOCIATED
WITH THE HDTV BROADCAST STANDARD





ure 2.2

incorporated by ISO/IEC into a four part standard, 13818, which specifies the digital television system (13818-1), video compression (MPEG-2)(13818-2), audio compression (13818-3), and compliance (13818-4). The ITU developed a set of digital television standards (ITU-T H-series) utilizing the same technology and based on MPEG-2 video compression. The video compression standard H.262 is the same as ISO/IEC 13818-2. These standards are essentially all encompassing "tool boxes" whose capabilities exceed the requirements of any one type of television system. Conversely, almost any digital television system design can be specified by drawing on the applicable contents of these standards.

The United States HDTV standard for broadcasting did precisely this; namely, incorporated the compression technique, and selected profiles and levels, conventions, syntax, and formats from ISO 13818 as a major part of its standard.

The standard is embellished and completed by a number supportive documents. However a different audio standard was developed. The HDTV standard was developed specifically for broadcasting applications; but it most likely will also be used in cable systems, and in common carrier systems such as ATM. The details are presented in subsequent sections.

The ITU standards were developed for both broadcast and non-broadcast applications. A series of H standards form the non-broadcast ITU standards and are rapidly being incorporated into a wide variety of television systems internationally and within the U. S., such as video-to-the-home distribution, direct satellite broadcast, video teleconferencing, motion video disks, video tape recorders, etc. Each specification for each of these is completed by invoking additional defining standards. Detailed information is provided in Section 6.

These two standards are obviously of direct interest to the Government.

3. BROADCAST STANDARD STATUS REPORT

3.1. Present Status

The status as of this writing is that the HDTV/SDTV standard has been approved by the ATSC membership in October. The standard was submitted to the FCC in November 1995 for approval. Subsequent to declaring the HDTV standard the U.S. national television standard, the present implementation plan provides for several years of simulcast operation; that is, both NTSC and HDTV video will be broadcast simultaneously to permit a reasonable transition from one system to the other. Presently this period is anticipated to be between 10 and 15 years.

3.2. Organization of the U.S. HDTV Standard

The standardization process of HDTV and incorporated SDTV standards in the United States is described above. The documentation of the United States broadcast standards effort, including the incorporation of international standards as appropriate, has been accomplished by the ATSC. The following is a broad outline of the proposed United States digital television broadcast standard.

The HDTV standard is composed of three basic ATSC documents and five standardizing annexes, each defining the specifications for a particular applicable technology. The ATSC documents include the "ATSC Digital Television Standard", an explanatory "Guide to the Use of the Digital Television Standard for HDTV Transmission" and a "Digital Audio Compression (AC-3) Standard". The annexes are tabulated below:

Annex A,	Video System Characteristics
Annex B,	Audio System Characteristics
Annex C,	Service Multiplex and Transport System Characteristics
Annex D,	RF/Transmission Characteristics
Annex E,	Receiver Characteristics

Each document incorporates other standards by reference. These references consist of two types;

a) Normative References, (provisions within these documents constitute provisions of the standard by reference) and
b) Informational References.

To complete the content of the HDTV Standard, the titles, source, number, date, and status of these references are tabulated below by annex.

ATSC Digital Television Standard for HDTV Transmission

General References

MPEG-2 Systems, ISO/IEC 13818-1, International Standard (1994)

MPEG-2 Video, ISO/IEC 13818-2, International Standard (1994)
Digital Audio Compression (AC-3) ATSC Standard, A/52, (1994)
Guide to the Use of the ATSC Digital Television Standard, ATSC T3/59 (1995)

Video System Characteristics, Annex A

Normative Reference (to the extent indicated)

MPEG-2 Systems, ISO/IEC 13818-1, International Standard (1994)
MPEG-2 Video, ISO/IEC 13818-2, International Standard (1994) Info
Standard for Television, 1920 x 1080 Scanning and Interface, SMPTE 274M, (1995)
Proposed Standard for Television, 1280 x 720 Scanning and Interface, SMPTE S17.392, (1995)
Encoding Parameters for Digital Television Studios, ITU-R BT.601-4.

Audio System Characteristics, Annex B

Normative References (to the extent indicated)

Digital Audio Compression (AC-3) ATSC Standard, A/52, (1994)
AES Recommended Practice for Digital Audio Engineering - Serial Transmission Format for Two-channel Linearly Represented Digital Audio Data, AES 3-1002 (ANSI S4.40-1992)
Specification for Sound Level Meters, ANSI S1.4-1983.
Sound Level Meters, IEC 651 (1975).
Integrating/Averaging Sound Level Meters, IEC 804 (1985), Amendment 1 (1989).

Service Multiplex and Transport Systems Characterization, Annex C

Normative References (to the extent indicated)

Digital Audio Compression, ATSC Standard A/52, (1994).
MPEG-2 Systems, ISO/IEC IS 13818-1, International Standard, (1994).
MPEG-2 Video, ISO/IEC IS 13818-2, International Standard, (1994).
MPEG-2 Compliance, ISO/IEC CD 13818-4, MPEG Committee Draft, (1994).

RF/Transmission Characteristics, Annex D

No normative or informative references.

Receiver Characteristics, Annex E, (Informative)

Informative References (to the extent indicated)

47 CFR Part 15, FCC Rules
EIA IS-132, EIA Interim Standard for Channelization of Cable Television
EIA IS-23, EIA Interim Standard for RF Interference Specification for Television Receiving Devices and Cable Television Systems

EIA IS-105, EIA Interim Standard for a Decoder Interface Specification for Television Receiving Devices and Cable Television Decoders

Additional documents relative to the standards were developed by the ATSC.

Additional annexes for the Digital Audio Compression Standard (AC-3)
Program Guide for Digital Television
System Information for Digital Television
Compliance with the Digital Television Standard

The ATSC Standard document can be accessed via the Internet as follows;

anonymous ftp
ftp.atsc.org/pub/Standards
World Wide Web
http./www.atsc.org

3.3. Tests Completed, in Progress, or Planned

3.3.1. ACATS Prototype Tests in Alexandria, VA

These tests have accomplished their initial purpose which was to verify that the HDTV system (and prototype hardware) as proposed by the Grand Alliance performs the functions required by the proposed HDTV standard (and, conversely, that the standard describes an acceptable HDTV system for the United States).

The entire HDTV system is very complex and therefore tests will continue to verify various features of the system and to resolve any issues which may arise.

3.3.2. ACATS off-the-air HDTV-NTSC Comparison Tests in Charlotte, NC

The purpose of the NTSC - HDTV tests was to verify the results of the laboratory testing of the Grand Alliance prototype HDTV system as well as evaluate the performance of the HDTV transmission method under actual off-the-air conditions using existing, conventional broadcast transmitters and antennas. The tests verified performance of 8-VSB modulation, and performance as a function of signal strength, interference, topographic, and environmental conditions.

Phase 1 of the Charlotte off-air tests was completed in August. In these tests both HDTV and NTSC signals were broadcast by two conventional TV broadcast transmitters. HDTV and NTSC reception were compared. The tests were performed using a mobile van containing the equipment used for testing mounted in a fixed configuration. Evaluation was on both an objective and a subjective basis. Subjective evaluations were made by trained observers. Over 80 sites were used in the evaluation. The sites were selected from a list of sites previously evaluated for NTSC signal reception. The selection included sites with excellent reception and sites with a range of impairments in the received signal at various distances from the transmitter. The final report of Phase 1 was presented to ATSC in late September.

Phase 2 of the Charlotte off-air testing was completed in late September. These tests further evaluate adjacent channel interference between NTSC and HDTV. Sites using indoor antennas were also used as test sites because of their unique reception characteristics. Test were also made to evaluate the performance of the HDTV system on cable using 16-VSB modulation.

Final reports became available in October of 1995 and indicate that performance was excellent.

4. FUNCTIONAL HIGHLIGHTS OF THE HDTV SYSTEM

4.1. Concept of the HDTV System

The basis for all of the HDTV digital systems used or planned for the United States is the MPEG-2 compression standard as defined in ISO 13818-1, 2, 3, and 4. There are basically two types of digital video transmission systems; broadcast and non-broadcast (which include all applications which need not comply with the broadcast standard). The U.S. broadcast HDTV system incorporates a subset of ISO 13818 and the ISO transport protocol, as well as Dolby AC-3 digital audio and vestigial sideband modulation. For non-broadcast television systems, the ITU H.262 standard (related to ISO 13818) and the terminal specification H.320 are already widely in use for applications such as video teleconferencing equipments and systems. The use of these standards assures compatibility between video equipment and systems. Prototype equipments incorporating H.310 specifications are being tested in teleconferencing networks.

MPEG-2, as defined in ISO 13818, is a "tool box" of capabilities from which systems can be developed. The capabilities provided far exceed the capabilities required by any individual video transmission system. Broadcast systems, for example, are of necessity restricted to a moderate number of image formats in order to constrain the cost of the millions of home receiving and display equipments. The ACATS/ATSC utilized ISO 13818, selecting a specific subset of parameters, to form the proposed new digital US television broadcast standard. Thus the underlying concept of all digital television systems of interest to the Government, foreign, US broadcast, and teleconferencing systems, have their major concepts in common: and these are extremely different from the familiar analog NTSC transmission concepts.

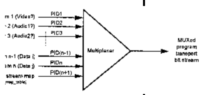
The digital broadcast television standards define a digital communication signal which can convey video, audio, text, data, and display related control information simultaneously within a transmitted data rate of approximately 19 Mbps for a wide range of applications. To achieve this comparatively low data rate, both the audio and the video signals are compressed, each with specified compression techniques. The version developed specifically for broadcast in the US is compatible with MPEG-2 MP@HL and will utilize MPEG-2 compression for video, AC-3 compression for audio, and VSB-8 modulation to transmit the signal within a 6 MHZ analog channel. (Note; use of 16-VSB will permit transmission of 32 Mbps within 6 MHZ in a friendly environment such as cable.) Other digital television systems (non-broadcast) use the same type of compression with different parameters and, as a result, can operate at different channel data rates tailored to various applications.

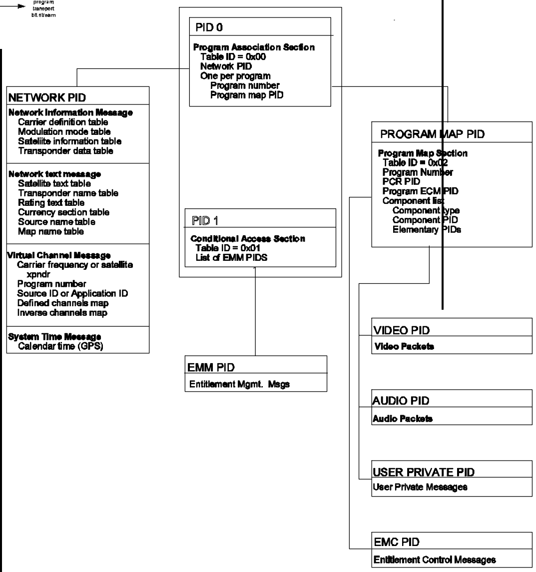
The preceding comments show that the HDTV standards are extremely different from the NTSC standards. No doubt the reader is familiar with the NTSC standard and therefore it will not be described here. The following paragraphs will provide a brief description of the digital HDTV video, audio, text, data, and control information transmission concept which is similar to that used in computer and data communication systems.

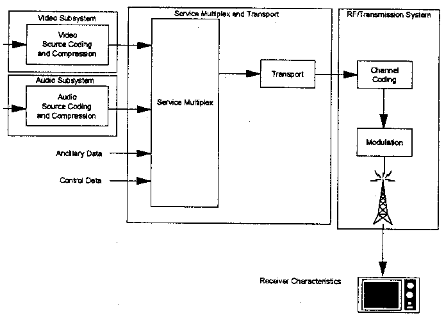
Broadcast HDTV transmission is a continuous digital bit stream called the transport stream which carries the program services. The individual signals to be carried in the transport stream (compressed video, compressed audio, data, etc.) originate as independent signals (elementary streams). These signals, in a digitized form, are organized by function into packets of data of specified length. Other packets are formed containing information about the network, program information, time, user messages, etc. The system appends an identifying header to each packet which specifies the packet's function and further defines the meaning of the packet contents. Packet length is specified at 188 bytes in length: a 4 byte header and 184 bytes of data. Each packet contains only one type of data. Packets may be transmitted in any sequence as dictated by the application. A total transport stream of 19.2 Mbps which can accommodate all of these packets, and may contain the selection of packet identifiers (PIDS) and packets transmitted in sequence is shown in Figure 4.1, "Information on the HDTV Transport Stream".

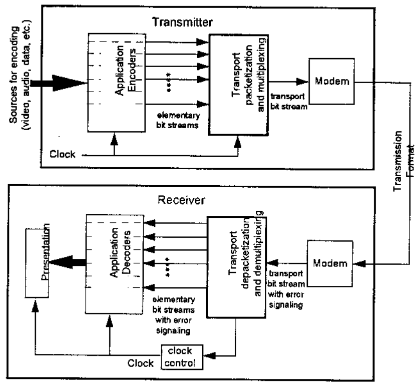
The transport data stream is assembled by a service multiplexer which selects the proper packet header and packet contents from the elementary streams in a user controlled sequence. In this manner the transport stream is formed as shown in Figure 4.2, "Multiplex Function to Form a Program Transport Stream". The figure shows an example in which several elementary streams are being combined in time sequence. The elementary streams together with their packet identifiers are: encoded digital video, encoded digital audio stream #1, encoded digital audio stream #2, two data streams, and a program map stream. The number, types and sequence of elementary streams will vary depending on the service to be provided.
Figure 4.3, "ITU-R Digital Terrestrial Television Broadcast Model", depicts the overall organization of the transmit end of a digital broadcast system. The channel coding and the 8-VSB modulator combine to permit the transmission of a 19 Mbps transport stream within a 6 MHZ channel. The service multiplexer combines a number of elementary signal streams into the HDTV transport stream. The main payload elementary streams, video and audio, are digitized and source coded and compressed in the video and audio subsystems before being multiplexed. For the ITU example, MPEG-2 techniques are used.

A simplified concept of an end-to-end transmission system is shown in Figure 4.4, "Organization of Functionality in a Transmitter-receiver Pair for a Single Digital Television Program". This figure highlights the recovery of each of the elementary streams and their subsequent decoding to reproduce the elementary signals for the display and the reproduction of the sound.


PID1
PID2
PID3
PID(n-1)
PIDn
PID(n+1)
Multiplexer
MUXed program transport bit stream


PID 0
Program Association Section
Table ID = 0x00
Network PID
One per program
Program number
Program map PID
NETWORK PID
Network Information Message
Carrier definition table
Modulation mode table
Satellite information table
Transponder data table
Network text message
Satellite text table
Transponder name table
Rating text table
Currency section table
Source name table
Map name table
Virtual Channel Message
Carrier frequency or satellite xpndr
Program number
Source ID or Application ID
Defined channels map
Inverse channels map
System Time Message
Calendar time (GPS)
PID 1
Conditional Access Section
Table ID = 0x01
List of EMM PIDS
EMM PID
Entitlement Mgmt. Msgs
PROGRAM MAP PID
Program Map Section
Table ID = 0x02
Program Number
PCR PID
Program ECM PID
Component list
Component type
Component PID
Elementary PIDs
VIDEO PID
Video Packets
AUDIO PID
Audio Packets
USER PRIVATE PID
User Private Messages
EMC PID
Entitlement Control Messages


Video Subsystem
Video Source Coding and Compression
Audio Subsystem
Audio Source Coding and Compression
Ancillary Data
Control Data
Service Multiplex and Transport
Service Multiplex
Transport
RF/Transmission System
Channel Coding
Modulation
Receiver Characteristics



4.2. Functional Highlights of the HDTV System of Particular Interest to the Government

Video Features:

High definition image in a single 6 MHZ analog channel or in a 19.2 Mbps digital channel.

Four standard definition images in a 19.2 Mbps digital channel or in a single 6 MHZ channel. For cable, 32 Mpbs can be transmitted in a single 6 MHZ channel.

Aspect ratio
Movie-like: 16 to 9.
Present ratio: 4 to 3.

Accommodates various display formats shown below as horizontal pixels by active lines:

	FORMAT	ASPECT RATIO	VERTICAL RATES
*	1920 x 1080	16:9	60I, 30P, 24P ***
		1440 x 1080	
*	1280 x 720	16:9	60P, 30P, 24P
		960 x 576	
		720 x 576	
**	704 x 480	16:9, 4:3	60I, 60P, 30P, 24P
**	640 x 480	4:3	60I, 60P, 30P, 24P
		352 x 288	

* Formats of U.S. HDTV broadcast
** Formats of U.S. SDTV broadcast

* Note: 640 x 480 is equivalent to NTSC and VGA in resolution.

** Note: vertical rates of 59.94, 29.97, and 23.98 are also permitted to accommodate present NTSC color signals as input formats.

*** Note: I= Interlaced scan, P= Progressive scan

Transmission picture rates:

The number of pictures per second which can be applied to the digital system as input video are shown above for the U.S. standard. Interlaced and progressive scanning are indicated as I and P respectively. Note that these rates are also the intended display rates but that, depending on the receiving device display capabilities, the pictures may be displayed in some other format. An example is the use of a set top box to receive the digital signal for display on an NTSC receiver. Conversion to an NTSC format is required.

Audio Features:

Primary audio features: Two channel stereo, five channel surround sound plus low frequency enhancement, program voice transmitted separately from effects and music, second language program channel, Dolby.

Associated audio features: commentary, hearing impaired, voice overs, emergency messages, narrative for visually impaired.
Loudness normalization and dynamic range control.

Other Features:

Data channel (2).

Privacy or Limited access. Eligible users defined by a match with the transmitted entitlement data.

Network data to define transmission path and characteristics where applicable as in satellite systems.

Program subtitles.

Emergency messages.

Program Guide

Virtual channels

5. TECHNICAL HIGHLIGHTS OF BROADCAST HDTV

HDTV

Bandwidth:
Only 19.2 Mbps is required for the transmission of a complete HDTV picture signal and the full 5.1 audio channel capability as demonstrated in tests over an ATM channel.

Digital baseband video signal compression and data rate:
Since the digital video signal is the major contributor to the transmitted transport stream or to the capacity required for storage, it is essential to efficiently reduce the total number of bits by efficient compression. The compression system is very flexible. The amount of compression required depends on the input signal format, quality of the reconstructed video, and the transmission data rate. For example, a high quality 1920 x 1080 format video signal sampled at 74.25 MHZ for a 30 frame per second signal at 8-bits per sample results in a digital bit stream of about 500,000,000 bits per second can be compressed using the MPEG technique based on the Discrete Cosine Transform algorithm and subsequent quantizing and entropy coding of the frequency domain coefficients. Figure 5.1 is a "High Level View of the Encoding Equipment". The compression reduces the video data rate so that the compressed audio, data, packet identifiers, and system management data can be added to the video and transmitted as a packetized transport signal at approximately 19 Mbps on a digital channel. Further processing with the 8-VSB algorithm permits transmission in a 6 MHZ channel. Other formats were previously discussed.

Digital baseband audio signal compression and data rate:
Analog audio signals are limited to 20 KHz except for the LFE signal which is limited to 120 Hz. The program audio is sampled at 48 KHz to at least 16-bit per sample precision (up to 24-bits is optional). After A/D conversion, the audio signal is converted from the time domain to the frequency domain. Bits are allocated to various features of the signal according to their psychoacoustic importance. The main audio service may be transmitted at up to 384 Kbps, associated audio services up to 128 Kbps. The combined bit rate of a main and an associated channel is limited to 512 Kbps. See Table 5-1.

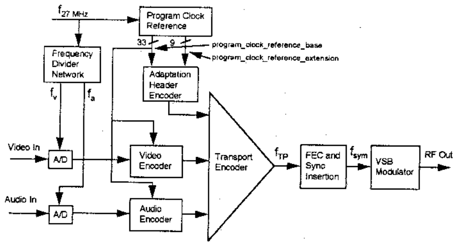


Table 5-1 Audio Bit Rates

Type of Service	No. of Channels	Typical Bit Rates (Kbps)
Complete main audio (1-5.1 channels) or Complete main with music and effects	5	320-384
Complete main audio or Complete main with music and effects	4	256-384
Complete main audio or Complete main with music and effects	3	192-320
Complete main audio or Complete main with music and effects	2	128-256
Visually impaired	1	48-128
Hearing impaired	1	48- 96
Dialogue	1	64-128
Dialogue	2	96-192
Commentary	1	32-128
Emergency	1	32-128
Voice-Over	1	64-128

Combined bit rate is limited to 512 Kbps.
e.g., Simultaneous transmission of main audio at 384 Kbps plus associated channels at 128 Kbps = 512 Kbps.

Modulation technique:

For broadcast, the digital, compressed television signal is channel coded and modulated onto a carrier using 8-level vestigial sideband modulation so that only a 6 MHz bandwidth is required for broadcast or cable transmission. For cable or other benign environment transmission, 16-level vestigial sideband modulation can be used so that the 6 MHZ channel has much greater capacity than a broadcast channel.

Input video signal formats;

The input signal structures are not limited to the formats which the receiver display system can reproduce. The HDTV system is devised so that the receiver will be provided with adequate information as part of the received signal to, in effect, reconstruct the image in the intended display format and then convert it to a display format which the receiver can reproduce. It is anticipated that this process will be used extensively during the initial phases of HDTV implementation in set top boxes which will utilize a standard NTSC receiver as the display device.

SDTV

The lower resolution image formats described constitute the SDTV images which can be accommodated over an HDTV broadcast channel. Several such images can replace the single HDTV image at the discretion of the channel manager. The broadcast standard defines the parameters for the transmission of SDTV to insure compatibility with the HDTV broadcast channel. Conversely, a lower data rate channel can be used for the transmission of a single SDTV signal. Equipment for this purpose is not available utilizing the U.S. Standard, however a wide range of equipment utilizing the MPEG-2 standard is available.

6. ITU DIGITAL VIDEO TELECOMMUNICATIONS

6.1. Overview of ITU Non-broadcast Video Recommendations

The preceding sections have described the features of the United States HDTV/SDTV standard in considerable detail. This standard and its features are important to the Government. The ITU-T H-series of non-broadcast standards ("recommendations" in ITU terminology) affects a possibly wider range of applications important to the Government particularly in the area of video teleconferencing. Some of these documents have not yet reached the full status of adopted recommendations but are determined (frozen except for minor editing), decided (approved for international balloting), or adopted (approved by international ballot and are now recommendations). Present schedules indicate that they will all be adopted within a year. Even though some may not yet have been adopted, they are being implemented into equipment/systems because of the technical capability and compatibility which they assure.

Prior to discussing the more important specifications of these standards, refer to Table 6-1 for a brief summary description of the range which the major non-broadcast recommendations encompass. Horizontally, the figure is a matrix in which the columns list the recommendation functions as headings; namely, system, video, multiplex, control/signaling, and communication interface. Vertically, the matrix rows have headings of the network type for which specific recommendations were or are being developed; namely, PSTN/mobile radio, narrowband ISDN, broadband ISDN/ATM, ISO Ethernet, and Ethernet/Token ring. The entries in the matrix are the applicable ITU-T H-series standards for each combination of function and transmission network.

Table 6-1 ITU Audiovisual Recommendations

NETWORK		TERMINAL STANDARD				
		SYSTEM	VIDEO	MULTIPLEX	CONTROL/ SIGNALING	COMM. INTERFACE
WAN	PSTN, MOBILE RADIO	H.324	H.263/H.261	H.223	H.245	V.34 Modem
	N-ISDN	H.320	H.261	H.221	H.242	I.400
	B-ISDN/ATM	H.321	H.261	H.2221	Q.2931	AAL I.363 AJM I.361 PHY.I.400
		H.310	H.261/H.262	H.222.0/ H.222.1	H.245	AAL I.363 AJM I.361 PHY.I.432
LAN	ISO ETHERNET	H.322	H.261	H.221	H.242	TCP/UDP IP
	ETHERNET, TOKEN RING	H.323	H.261	H.22Z	H.24Z	

Of particular interest are H.310 and H.320 system standards. They specify the system parameters for ATM/B-ISDN and N-ISDN network transmission respectively.

6.2. H.310 Terminals

The H.310 Recommendation defines a broadband, audiovisual, packetized, communications system and terminals which can also transmit data. The terminals incorporate MPEG-2 video compression operating from 64 Kbps to 13 Mbps. The recommendations include a specification for a Multipoint Control Unit which permits multipoint video teleconferencing. Two classes of terminals are defined: bidirectional terminals and unidirectional terminals. The latter transmit or receive only. Communication may be in one direction only; namely, from one terminal to many. Each class can be further divided by the intended application.

A system consists of interconnected terminal equipment, network, and multipoint control unit (where appropriate). The terminals have the ability to negotiate common capabilities. The capabilities of a 310 terminal are classified according to the following attributes:

video codec capability,
audio codec capability,
network adaption capability,
control & indication capability, and
other data capability.

Negotiable interworking between H.310 and H.320 terminals is possible under the conditions discussed in Section 6.4.

6.2.1. Video Codec Capability

The two classes of terminals are further categorized into main level and high level terminals in accordance with the highest level of resolution provided. The formats and resolution supported by each class of terminal are shown in Tables 6-2 and 6-3. Note that the inclusion of certain levels of resolution permit negotiable communication between different classes of H.310 terminals.

The resolution provided by the recommendations listed in Tables 6-2 and 6-3 are defined below:

H.261 Common Intermediate Format (CIF);	352 H x 288 V
H.261 Quarter CIF (QCIF);	176 H x 144 V
H.262 Main Profile Main Level (MP@ML);	720 H x 576 V
H.262 Main Profile High Level (MP@HL);	1920 H x 1152 V
H.262 Main Profile High Level 1440 (MP@HL-1440);	1440 H x 1152 V

Table 6-2 Characteristics of H.310 Main Level Terminal Types

TERMINAL TYPE	VIDEO		AUDIO		DATA	
	Mandatory	Optional	Mandatory	Optional	Mandatory	Optional
Receive Only	H.262 MP@ML	H.262 MP@HL H.262 MP@H14L	MPEG-1	MPEG-2	US	US
Send Only	H.262 MP@ML	H.262 MP@HL H.262 MP@H!4L	MPEG-1	MPEG-2	US	US
Receive and Send	H.261 (CIF & QCIF) H.262 MP@ML	H.262 MP@HL H.262 MP@H14L	G.711 G.722 G.728 MPEG-1	MPEG-2	US	T.120

Table 6-3 Characteristics of H.310 High Level Terminal Types

TERMINAL TYPE	VIDEO		AUDIO		DATA	
	Mandatory	Optional	Mandatory	Optional	Mandatory	Optional
Receive Only	H.262 MP@ML H.262 MP@HL H.262 MP@14L	US	MPEG-1 MPEG-2	US	US	US
Send Only	H.262 MP@ML H.262 MP@HL H.262 MP@14L	US	MPEG-1 MPEG-2	US	US	US
Receive and Send	H.261 (CIF & QCIF) H.262 MP@ML H.262 MP@HL H.262 MP@14L	US	G.711 G.722 G.728 MPEG-1 MPEG-2	US	US	T.120

US indicates that the standard is presently under study (5/95)

6.2.2. Audio Codec Capability

Audio capabilities are also specified for the types of terminals and are shown in Tables 6-2 and 6-3. Proper selection of the audio recommendations will permit audio communication between classes of H.310 terminals. Several of the audio recommendations are defined below.

G.711, (PCM)
G.722, (16 Kbps LD-CELP)
G.728, (7 KHz at 56/64 Kbps)
MPEG-1 (ISO/IEC 11172-3)
MPEG-2 (ISO/IEC 13818-3)

6.2.3. Control & Indication Capabilities

These capabilities using ITU-T Rec H.222 framing and channel aggregation provide the following as the more important features in the modes of operation listed;

Video frame synchronous
split screen indication
document camera indication
freeze picture release indication
closed caption

Capability exchange

Video frame asynchronous
loop back
video source indication
audio source indication
numbers, characters

6.2.4. Other Data Capabilities

These capabilities were not firm in the latest draft (5/95) but data can be packetized and multiplexed with other audiovisual data with either Rec H.222.1 or ATM layer multiplexing.

6.2.5. Network Capabilities

The network capabilities include the multiplex and synchronization, ATM adaptation, and transfer rate. Both unidirectional and bidirectional terminals will support constant bit rate transfer rates of n x 64 Kbps for n from 1 to (217-1) for the transmission and reception of H.222.1 multiplexed audiovisual signals. Performing the multiplication indicated, the system data rate can range from 64 Kbps to 216 x 64 Kbps or 13,824 Kbps (13.824 Mbps). The specific rates and standards to be used depend on the specific function and communication channel utilized. This information is rather detailed. The reader is referenced to the ITU-T Recommendation H.310 for this level of information.

6.3. Standards Related to H.310

The following is a partial tabulation of the ITU-T recommendations pertinent to H.310 terminals. From this it can be seen that the technology and the standardization process are thorough and well advanced.

Note; The dates, where shown in connection with each listing, indicate the anticipated date for adoption as a recommendation.

SUPPORT RECOMMENDATIONS FOR H.310 AND H.320

H.310 Line Transmission of non-telephone signals
Broadband AudioVisual Communications Systems and Terminals

H.320 ITU-T Multimedia Telephony Standard for ISDN, ATM, GSTN, and LANs.
Equipment Description.

H.221 Framing and channel aggregation.
H.222.0 System multiplex for ATM (Common text with ISO)(A)
H.222.1 H.32X specific features (11/95)
H.224 Data Link Layer for LSD/HSD
H.230 Control and indication BAS codes

H.231 Overview of the MCU
H.242 Call startup procedure
H.243 Details of multi-point operation
H.245 Control for H.324, H.323, and H.310 (11/95)
H.261 Video encoding and decoding
CIF (Common Intermediate Format) 352H x 288V.
QCIF (Quarter Common Intermediate Format) 176H x 144V.
Frame rates up to 30 fps
H.262 MPEG-2 video for ATM (A)
H.281 H.DLL app for far end camera control

AUDIO

G.711 Audio (PCM)
G.728 Audio (16 Kbps LD-CELP)
G.722 Audio (7 KHz at 56/64 Kbps)
ISO/IEC 11172-3 MPEG-1 audio
ISO/IEC 13818-3 MPEG-2 audio

DATA

T.120 Overview (2/96)
T.122 Multi-point communication service (A)
T.123 Audio-Visual protocol stack (A)
T.124 Multi-point communication service control (A)
T.125 Multipoint communication service protocol (A)
T.126 Still image transfer and annotation (A)
T.127 Binary file transfer (A)
T.AVCAudio-Visual Control (2/96)
T.GATGeneric Application Templet (2/96)

H.320 ON OTHER NETWORKS

H.322 H.320 on guaranteed quality of service LANs (11/95)
H.323 H.320 on non-guaranteed quality of service LANs (96)
H.321 H.320 over B-ISDN (ATM) (11/95)

GSTN VideoPhone (all 11/95)

H.324 Overview of VideoPhone
H.263 Improved video coder, 2 x H.261 quality at low rates
G.723 5.3/6.4 Kbps audio coder
H.223 Multiplex for VideoPhone
H.245 Control for ATM, PSTN, and LAN

I.363 ATM Adaptation Layer

6.4. H.320 Terminals

Information about H.320 terminals is include here because H.320 terminals can interwork with H.310 terminals (via CIF mode) and because, in the future, the H.320 terminal recommendation may be expanded to include an HDTV mode.

The H.320 Recommendations for a multimedia communication system were adopted by the ITU-T in 1990 and expanded in 1993 and 1995. These terminals include video, audio, and data communication and permit multipoint conferencing by means of a multipoint control unit also included in the standards. Equipment incorporating the H.320 recommendation is being produced by most major video system/teleconferencing equipment manufacturers (including those in the United States). Advances to the basic recommendation provide multipoint interactive data applications.

6.4.1. Video Codec Capability

The video compression is defined by the H.261 recommendation in the following formats:

CIF (Common Intermediate Format): 352 H x 288 V
QCIF (Quarter CIF): 176 H x 144 V
Frame rates up to 30 frames per second.

6.4.2. Audio Codec Capability

The audio compression is defined by the following recommendations:

G.711: (PCM)
G.722: 7 Khz, 56/64 Kbps
G.728: 16 Kbps

6.4.3. Other Major Applicable Recommendations

Control and indication BAS codes:	Rec H.230.
Framing and channel aggregation:	Rec H.221.
Call startup:	Rec H.242.
Multipoint operation:	Rec H.243.
Multipoint overview:	Rec H.231.

6.4.4. Network Capabilities

Communication can be accomplished at the following transfer rates:

n x 56/64 Kbps, where n ranges from 1 to 24.
n x 384 Kbps, where n ranges from 1 to 5.
T-1 and E-1 rates,
and fractional T-1 rates.

Utilizing network interface recommendations existing or being developed, H.320 terminals can provide communication over common carrier circuits including GSTN, ISDN, LAN (Ethernet/token ring), and ATM/BISDN (LAN/WAN).

7. APPLICATIONS OF HDTV/SDTV FOR THE FEDERAL GOVERNMENT

7.1. Implications of Digital HDTV/SDTV for the Government

The change from NTSC standards to digital video standards to utilize its advanced features is not an event which will occur in the future: the change is in process now and accelerating very rapidly. For example, digital MPEG video is being utilized in direct satellite broadcasting, interactive digital video, digital motion video discs, video teleconferencing, personal communications, digital imaging for the home and business, open architecture video dial-tone, video on demand, telemedicine, video storage of documents, on-line services via the PC, and Internet video access. These services are all utilizing some form of digital television standards based on MPEG-1 and MPEG-2. Therefore, the Government must consider use of digital video rather than NTSC analog video or even digitized NTSC video for all television type applications in order to avail itself of these new capabilities and because of impending NTSC obsolescence. This applies to high or standard resolution applications. NTSC input and output components can still be used with a digital transmission system provided NTSC specifications are adequate for the application and the proper interface equipment is utilized for digital compression and transmission.

7.2. Standards of Interest to the Government

Given that the television applications will utilize digital techniques for generation, storage, transmission, and display, it is essential that digital video standards are observed if the benefits listed above are to be achieved. The standards ensure compatibility among users and compatibility with the communication channels.

There are several existing digital television transmission/distribution standards. In the area of video transmission among Government agencies, the ATSC Digital Television Standard for HDTV Transmission and the ITU H series are of primary interest. They are very similar in that they both utilize portions of the MPEG-2 video compression technique standardized in ISO 13818-2 and ITU H.262 which specify digital video profiles, formats, and levels from high definition to comparatively low definition covering a very wide range of applications.

The ATSC HDTV Standard has been developed primarily for the broadcast of HDTV in the United States as described above. A version of this standard will probably also be used for cable video distribution. This technique processes the HDTV video signal (or SDTV signals) together with up to five audio channels and up to two data channels into a digital bit stream of up to 19.2 Mbps. This digital signal can then be coded using 8-VSB for terrestrial broadcast. A 32 Mbps version can be coded using 16-VSB for transmission on cable. The video compression technique utilizes portions of the MPEG-2 technique as defined in ISO 13818-2. The transmitted vestigial sideband signal fits into the present NTSC broadcast transmission spectrum.

The ITU H series of standards is the ITU counterpart to ISO 13818. Both, like the ATSC HDTV Standard, utilize MPEG-2 compression. ITU H series has been developed for the total spectrum of broadcast digital video applications and for non-broadcast applications of digital video. The H series is defined in detail in Section 6. A family of standards have been developed to provide terminals which satisfy a wide range of applications. Refer to Figure 6. The signal adaptation and interface functions of terminal equipments may include an ATM adaption layer, ATM function, and a physical interface to a B-ISDN network, interface to Ethernet and Token Ring, N-ISDN, PSTN, and mobile radio.

7.3. Features of HDTV Digital Television of Direct Interest to the Government

7.3.1. Resolution

Of particular interest to the Government is the fact that digital video, as defined in the MPEG derived standards, can provide a wide range of system resolution from which an optimized format can be selected for a specific application thereby assuring excellent performance and minimum transmission bandwidth or storage requirements. The ability to provide high resolution (pixels per image), together with digital reconstruction of the pixels at the receiver, permits the display of crisper images much higher in resolution than those achievable with stored or transmitted conventional analog signals.

The MPEG derived standards define HDTV images with up to 1920 picture elements per image width and as many as 1080 active lines per image height. Compare this to a conventional NTSC analog television signal with 480 active lines and 640 pixels per line. This example assumes both images are digitally generated and does not need to consider the effects of Kell Factor and the modulation transfer function of an input device. Therefore, the HDTV presentation has 1920/640 or three times as many pixels per line and 2.28 times as many active lines per image. This results in an almost seven fold increase in the total number of pixels per picture and can be interpreted as seven times as many equal quality alphanumeric characters which the HDTV system can display as compared to NTSC systems. Furthermore, the use of digital transmission and reconstruction of pixels at the display location will eliminate any pixel degradation which can occur in an analog transmission. Note that the HDTV presentation aspect ratio is 16:9 as compared to the NTSC aspect ratio of 4:3.

The result is that the HDTV presentation of any form of documentation, graphics or text, which may be transmitted and displayed will be substantially superior to that which was previously possible using the NTSC standards. In the area of Government applications, maps, documents, spreadsheets, briefing material, can contain far more information and be displayed in a much clearer presentation.

The same improvement in quality is true for images of any type.

7.3.2. Color and Gray Scale

Of course, the previous discussion on resolution also applies to color and gray scale material such as photographs, briefing charts, etc.

The digital television signals can be generated directly in digital form (e.g., by a computer) in which case the gray sale or color of the image is precisely defined. If the signal input to the system is in analog format, (e.g., from a television camera) the standards specify precisely how that signal is to be converted into digital form, preserving the gray scale and the colorimetry accurately. Once in digital form, the signal can be transmitted over a digital channel with no degradation in either gray scale or colorimetry. Degradation of both is common with analog signals due to non-linearities and phase shifts which often occurred in an analog transmission channel or storage device. The color integrity of some items key to Government applications such as areas of a map, color coded graphs, color photographs, etc., is assured by digital transmission and storage.

7.3.3. Motion Video

The MPEG-2 coding algorithm was developed by the Motion Picture Experts Group from which it derived its name. It was specifically developed to compress video picture signals which contained image motion with a minimum of motion degradation. Motion within an image renders some compression techniques comparatively ineffective. The MPEG-2 algorithm adapts to the amount of motion within a picture sequence. Sequences with little motion can utilize a picture prediction technique minimizing the number of frames and, correspondingly, the amount of data that must be transmitted. Sequences with motion are accommodated by predicting the amount and direction of motion. In this way two successive frames, have a much higher degree of correlation between the original frame and the motion predicted frame and will result in higher compression and better motion presentation.

The use of the 60 frames per second transmission mode which is achievable with HDTV can provide better motion presentation than the 30 frame per second interlaced NTSC system depending on the amount of motion involved.

The uncompressed NTSC system (present broadcast system) does have some advantage in motion presentation over a highly compressed HDTV system (and even more so over compressed NTSC systems). The uncompressed NTSC system transmits each field of interlaced video pixel by pixel as it occurs so that what the camera-sees-is-what-you-get. (Image smear in the pick-up sensor is not included in this discussion.) The method of compression/decompression can affect motion presentation by introducing artifacts into the displayed video and by updating the display at a lower than normal rate. The MPEG-2 compression algorithm is optimized to minimize the amount of such distortion to an acceptable level while achieving exceptional amounts of video compression. At data rates used for broadcasting, the subjective tests have shown that these distortion effects are not obvious in scenes containing 'normal' amounts of motion.

A very widely used and accepted format for video teleconferencing is H.320, Common Intermediate Format, 352 x 288 elements. The most commonly used data rate for transmission of video in this format is 384 Kbps which includes audio. The displays produced by these systems are high quality and are widely accepted as indicated by the great number of systems in use. It is expected that transmitting HDTV in 1280 x 720 format at T-1 rates (1.544 Mbps) will produce displays just slightly lower in quality from a motion standpoint but, of course, much higher in resolution. Transmission at higher data rates will correspondingly reduce motion artifacts.

7.3.4. Compression

A feature of the MPEG-2 type digital video transmission is the availability of highly advanced video compression techniques. The advantage of the use of these techniques is that, for a given transmission channel capacity, the picture quality is far better than with the use of other compression techniques. Conversely, the compression parameters can be set to achieve the amount of compression required in order to utilize available digital channels. The remarkably high compression ratio is the result of a combination of techniques used to achieve that goal. For example, motion compensation, inter-frame and intra-frame coding, predictive coding, and bi-directional predictive coding can all be employed. Each provides exceptional benefits for picture streams with specific characteristics. The compression itself consists of transform coding, coefficient quantization, and entropy coding of the result. Again as an example, motion picture film provides only 24 images per second; the MPEG-2 system can compress and transmit this signal at 24 frames per second and convert it to video for display at 30 or 60 frames per second at the receive end greatly reducing the channel traffic requirements. Transmitter encoder and receiver decoder negotiate these characteristics in duplex systems. In broadcast systems, the decoder is informed of the technique used by the encoder and operates with the proper parameters to display the image in the format specified or in a format compatible with its incorporated display (it is not anticipated that receivers will be able to display all formats as a matter of economics).

In recent teleconferencing systems, in order to effect the economies of off-the-shelf cameras, monitors, etc., NTSC components have been utilized. However, the codecs have digitized the input analog NTSC signal and then compressed it utilizing the MPEG-2 compression process. These hybrid systems will exist for some time and are a good compromise for systems requiring that level of display quality.

Broadcast and closed circuit video are not the only users of the MPEG-2 standards. For example, these compression techniques are also incorporated into systems using CD ROM disks to store motion pictures and into high quality video tape systems. In fact, many PCs are now sold with the MPEG algorithms incorporated onto an installed board for decoding and converting CD ROM signals into motion picture presentations. Video servers to support video-on-demand systems are being planned utilizing the MPEG-2 compression and transport.

7.3.5. Noise Immunity and Error Correction

Transmission of any sort is degraded by noise added to the signal by the transmission channel. NTSC television signals degrade gradually as the signal strength and the signal-to-noise ratio decrease. The design of the synchronization aspects of the NTSC signal permit it to perform satisfactorily through a wide range of signal-to-noise ratio. Digital television signals, of course, are also contaminated by noise. However, digital signals can be recovered with very low error rates up to a threshold signal-to-noise ratio at which point they normally degrade rapidly. Expressed in path parameters, the digital signal can accept higher path loss than NTSC signals for satisfactory pictures.

The MPEG-2 type systems have been tailored to inherently minimize this sensitivity by transmitting an error detection and correction signal. In the case of relatively low error rates, the errors can be corrected. In the case of severe burst errors, corrupted frames may be discarded and previous frames displayed until the next error free frame is received. A retained frame is difficult to detect and viewing quality is high. The channel error rate must be very high for this to occur. Therefore, the digital television transmission should outperform the analog NTSC transmission in a noisy environment up to the threshold. The results of the tests in Charlotte have given a clear indication of this feature.

7.3.6. High Quality and Multiple Channel Audio

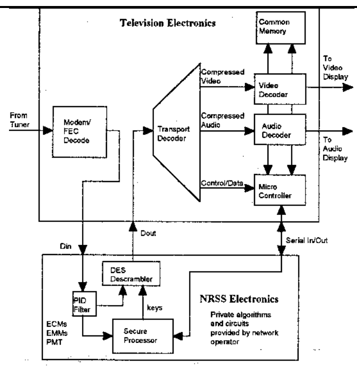
The quality of the HDTV audio main channels is often referred to as "CD" quality. As indicated previously, the transmitted audio frequency response is extended to 20 KHz. The audio compression method reconstructs the dynamic range to provide a realistic reproduction of the audio signal.

Multiple audio channels are intended to transmit stereo audio, surround sound, and all of the features previously listed. The reproduction of sounds can be very realistically portrayed, greatly contributing to establishing even a very complex audio environment.

For Government applications it is practical to transmit the primary voice signal on one channel, and a secondary voice signal of a different security level or a different discipline on another channel. Two or more levels of briefing can be conducted simultaneously using the same video. Second language transmission is one of the broadcast applications of the second audio channel. The audio channels reserved for commentary, dialogue, voice-over, and emergency message channels all provide the ability to direct private verbal messages to alternate groups of attendees at video teleconferences and briefings. Hearing impaired and visually impaired channels support handicapped viewers.

7.3.7. Privacy/Conditional Access

HDTV systems complying with the broadcast standard, provide an inherent privacy/conditional access capability by means of which only receiving equipment provisioned with the proper entitlement technique can receive the designated video and audio signals. Entitlement can be enforced from the transmit end by sending unique entitlement codes. Receivers are provisioned with private algorithms permitting only those receivers which respond properly to unique transmitted entitlement bit sequences to decode and present the transmitted video and audio signals. This is not a form of encryption but provides a first order user qualification or system privacy. In the commercial world, this technique is used to control reception of "pay" TV channels from the head end. Figure 7.1 shows the implementation of the conditional access feature using the National Renewable Security System.



7.3.8. SDTV

If the Government were to implement an HDTV channel between two locations using the HDTV standard, it would be possible to transmit up to four standard resolution digital video signals (SDTV) within the same 19.2 Mbps channel should the situation warrant. The packet identifiers control the receiver to assure that the proper packets are decoded and directed to produce a picture of the selected video signal. The resolution which the SDTV presentation can achieve is the lower end of the resolution parameters listed above for HDTV and in general equate to present NTSC and PC generated video. Most likely, if a single signal of this quality satisfied an application, a lower data rate channel would be selected as the transmission medium; e.g., T-1 or even fractional T-1 rather than utilize a full 19 Mbps of the HDTV channel.

7.3.9. Data

The HDTV system standard permits transmission of data as one of its payloads. The data is also transmitted in 188 byte packets as is the video and audio. Tests of transmitting data together with a picture signal indicate that the type of data does affect the packetization or transmission. The tests have been made with an ancillary data rate of up to 4 Mbps.

7.3.10. Transmission

In the broadcast version of the HDTV standards, the digitization and the MPEG compression permit up to 4 picture signals to be transmitted within the spectral confines of a single NTSC 6 MHz analog broadcast channel with the same quality as a previous single NTSC picture. Conversely, a much higher resolution HDTV can be transmitted within the same spectrum together with all of the audio features described above. In addition, the benefits of consistent color and quality are preserved by use of the digital signal. As a grand example, with the digital satellite broadcast systems such as PrimeStar Partners LP, DirecTV, and USSB, the subscriber can receive up to 175 channels within the continental U.S. These systems use a version of digital MPEG processing and compression.

Cable television carriers are formulating their version of MPEG standards to transmit television signals via their cable plants. Using 6 MHz NTSC type channels and 16-VSB modulation, the number of channels which can be transmitted can be increased and the quality improved.

The broadcast HDTV signals in their digital form can also be transmitted via conventional communication channels. The transmission of MPEG type digital video signals can vary from 19.2 Mbps down to 128 Kbps depending on the resolution, motion, image quality required and standard utilized. For this application the user is referred to the ITU H.320 digital television standard designed primarily for use with circuits of this type. In general, two types of circuits are used for digital video applications: dedicated non-switched, and switched circuits. Dedicated circuits are used to interconnect high usage applications. The data rate of the circuits is determined by the characteristics of the video which they are to convey. They may range from 128 Kbps ISDN, through fractional T-1, T-1, and occasionally to full DS-3. Switched circuits are available up to T-1 or higher where ATM, etc. is available. The range of data rates permits the transmission of a wide variety of image formats with good motion capability. In the future, widespread availability of ATM and Broadband ISDN will provide switchable circuits with even greater bandwidth. The 19.2 Mbps digital video has been transmitted via ATM in Charlotte as part of a system test.

7.3.11. Flexibility

The utilization of digital packet transmission and the fact the packets can be transmitted in any combination and/or sequence gives the HDTV/digital television systems a tremendous flexibility which can be utilized to optimize a television communication system for many specific purposes. The mix of packet types transmitted such as video, audio, data, or any of the other ancillary functions can customize the communications link to many specific applications such as teleconferencing, spread sheet analysis, simulation, command and control, telemedicine, multi-discipline briefing, etc. This feature is deceptively powerful.

7.4. Specific Government Applications of Digital HDTV/SDTV

It is impossible to list the myriad of applications of television which may be of interest to the Government. Therefore they will be addressed on a generic basis below. In general, the governmental applications parallel the applications which occur within the commercial field. Equipment manufacturers are developing digital hardware and systems to satisfy these applications.

7.4.1. Briefing

An essential application of television within the Government is briefing. The visual display requirements of briefings have often been curtailed from what might be desired so that they can be satisfied by NTSC television capabilities, PC display standards, and custom pseudo-standard 1000 line systems. Briefings which require higher resolution static images are being supplemented by 35 mm slides. Presently high resolution motion images are a problem. Multiple views of a scene require a number of projection and display devices with the attendant logistics involved in presenting the proper display at the proper time. Insets of one image into another are limited to the overall system resolution. Use of slides also limits the briefing to one location.

The digital television standards permit resolving many of these limitations by use of just one television signal. Resolution can be selected to suit the application from 1920 pixels x 1080 lines down through PC and NTSC resolution to as low as 352 x 288 accommodating a wide range of image material. The high resolution mode rivals 35 mm slides in resolution and colorimetry and provides motion capability not readily achieved in any other way. Furthermore, as many as 4 pictures can be conveyed on one signal and presented on multiple displays to provide multiple views of an object/situation under discussion. This simultaneous multi-view can present wide angle and narrow views, map and action at designated locations, image of the speaker as well as the picture(s) of interest. (This is also a great aid in providing depot advice to field crews in repair operations.) Insets of one image into another are easy to achieve and provide a "clean" presentation because the signals are digital. The use of multiple voice channels permits briefing several levels or disciplines of attendees simultaneously with the same video material.

Since all of the capabilities required for the briefing can be conveyed on a digital bit stream over conventional communications circuits, remote briefing of a much higher quality can easily be achieved. The briefings can be transmitted to remote locations; e.g., briefings from the field to headquarters or vice versa. Briefings can be internal to a building or complex using the digital LAN. The viewers in such an application can participate through the display on their desk top PC equipped with an MPEG board.

Encryption of the high resolution digital video signals is more easily achieved since the data rate for a given quality of image is lower as a result of the MPEG compression algorithm.

7.4.2. Assembling Presentations

The features of digital video together with expected features of digital television storage devices should combine to provide a simple method of assembling presentations, briefing and training material. Seamless segmentation of sequences and insets should be superior to the quality presently achievable. Storage on random access storage devices such as conventional large scale hard disks utilizing personal computers should simplify and speed up access of video clips. The high resolution capability will permit direct use of real time material without the need for processing to be sure that the material is readable or provides an image of adequate clarity. Color will remain consistent from input material through processing to the final product without concern that color artifacts are generated due to the type of material being televised. The digital form of the presentations will retain their quality as compared to film and analog tape.

7.4.3. Storage/Retrieval

Systems exist for the storage and retrieval of NTSC video and single frame higher quality images. Storing and efficiently retrieving motion images particularly with high resolution has been a problem. Digital television and mass digital storage are being combined to provide a cost effective solution. Digital video disk technology in the form of a CD ROM and in the form of mass storage servers, and digital video tape recorders are being developed for storage of motion video.

The digital aspects of video tape storage permit high speed retrieval and random access to short segments as might be used in a briefing or teleconference. Digital video tape cassettes have also been demonstrated. The requirements of motion archival video libraries are also satisfied. The quality of the stored picture sequences remains consistent with time. Previous video recorders were restricted to NTSC resolution and color quality. With the digital standards, the entire range of resolution can be stored on the digital tape recording device as long as the digital video data rate is compatible.

Mass digital disks are being developed for video-on-demand applications. These devices will be ideally to situations where rapid access to a high volume of motion image storage is required.

7.4.4. Surveillance

Video systems used for surveillance can benefit from the higher resolution achievable. The area can be observed in much more detail or a much larger area can be observed at the same linear resolution as is presently obtained with NTSC systems. The need for zooming can be reduced. Personnel verification systems can provide much clearer images of the personnel to be identified, for example, by providing up to 7 times as many pixels within the full facial area used. The colorimetry will be more consistent. Signal transmission being digital will be simpler.

7.4.5. Video Teleconferencing

Video teleconferencing has become a way of life in the commercial world and within the Government. The technology utilized in video teleconferencing has, to a great degree, already incorporated digital video and one set of MPEG compression standards. Up until recently, the resolution capability of these systems were limited to NTSC equivalent or lower. Input and output video were, and still are, NTSC signals in order to utilize standard off-the-shelf devices.

The ITU-T H.262, ITU-T H.310, and ITU-T H.320 standards for coding moving pictures and for broadband and narrowband audiovisual communication systems and terminals are now being applied to the design of video teleconferencing equipment and systems. These standards define terminals/systems which provide all of the features described above in the areas of compression and resolution. They included standards for the negotiation of capabilities among terminals and for the conversion of the signal to standard communication interfaces. In a fully implemented terminal, many of these features are operator selectable so that the terminal can be configured for the specific application at hand. In addition, the transmit terminal can negotiate with other terminals in the teleconference to establish the highest level of compatibility prior to commencing the conference. The result is that the highest level of communication can be established based on user requirements and capabilities of attendee terminals.

The ITU-T standards include standards for the conversion of the digital video/audio signals to the format required for conventional communications channels. A feature of particular interest is the formatting of the signal for ATM transmission utilizing a B-ISDN channel which are appearing in selected areas and will be readily available in most areas in the near future.

7.4.6. Simulation and Training

Simulation and training are best accomplished if the media provides a realistic environment of the process of interest in both pictures and in sound.

The pictures must be accurate in detail to be truly effective; resolution, color, and motion. Although useable, NTSC simulation and training often falls short in several areas. As has been described above, digital television can provide up to 1920 x 1080 picture elements, about 7 times that of NTSC. This also compares favorably with 35 mm motion picture film used today in the more critical applications. Digital television can also be displayed in 60 Hz progressive format for high brightness flicker free presentation. For less critical applications, a lower resolution digital television format can be used to reduce the data rate or storage volume required.

The high quality audio and the surround sound and other ancillary features of HDTV can greatly enhance the realism of a simulated or actual televised environment for training or simulation applications. Training or simulation of field events must ideally include the stress under which such events take place. The multiple audio channels, wide frequency response, wide dynamic range, and the low frequency enhancement features provide an ideal media for this type of training and simulation. Ancillary audio channels can provide crew training by providing individual instructions/environment for each discipline.

Applications which take place in a benign environment benefit from the high quality of the audio presentation which can maintain a relaxed atmosphere for the participants without the unintentional stress created by a low quality, noisy presentation.

7.4.7. Use on LAN

The digital television system lends itself uniquely to local teleconferencing where the users are located within a single building or a campus. Two techniques can be used; HDTV format or other digital television formats. Each has its own advantages. In either case, the PC may play a prominent part in that it can provide the display, house the MPEG card(s), audio decoder and driver, and provide the system operation management.

If the building or campus is provided with a distribution system which can transmit the 6 MHZ HDTV signals, the multi-channel broadcast/cable transmission method can be utilized much as in the manner of the present cable approach with all of the added benefits of high resolution video, surround sound and multiple channel audio, and data channels. This approach would utilize off-the-shelf equipment as it becomes available.

The distribution of HDTV signals can also be accomplished in digital form over LAN type distribution systems. The use of wideband wiring such as Category-5 cable provides the capability of transmitting multiple channels over a single LAN and utilizing a PC as a desk top video teleconferencing interface device.

7.4.8. National Information Infrastructure (NII)

One of the foremost items in information systems today is the National Information Infrastructure (a national priority). The proponents of the HDTV standard and the NII foresee HDTV broadcasting and cable transmission providing digital data to the public. They further envision that an upgrade to the terminal or receiver would yield an NII ready information appliance. Two way communication could be possible on cable.

On a more personal basis, information interchange is firmly established on a PC and common carrier basis. This technology is developing at a tremendous rate, driven by the personal interest of the users and support of the government. At present, imagery interchange is still a minor portion of the information interchange although considerable effort is being put into developing coding and decoding algorithms which can be implemented entirely in software. The resulting image presentations will fill some of the present requirements but may have some of the following characteristics:

Low frame rate (poor motion portrayal),
Low number of pixels per frame (poor image quality),
and/or
Poor gray scale/color rendition.

It is expected that within a short period of time users will be dissatisfied with the quality of imagery, motion portrayal will become a higher priority requirement, and higher data rate channels will be available economically. The digital standards will then play an important part in the NII. The following advantages will be realized:

Users can interface and utilize standardized image storage systems which are presently designed to digital TV standards,
Users can communicate with a much larger segment of the world wide population because of a common standard,
The demand for higher image quality can be satisfied: resolution, color, gray scale, and motion,
Data channels will be available to accommodate the data rate which may be required to achieve these goals,
MPEG circuit boards for incorporation into PCS are becoming an almost standard PC ancillary item.

7.4.9. Multi-media Channel Concept

A single communication circuit may satisfy many of the Government interfacility communications requirements by using the digital television approach.

t is expected that the communication requirement between Government facilities may be quite varied and, in fact, may vary daily or even hourly depending on requirements. For example, data, voice, and video requirements may always be required, but the relative amounts of each may vary considerably with time.

The HDTV/SDTV system as described previously is a packet transmission system in which the order and the frequency of transmission of packet types is determined by the channel user. The packet types are many and varied but for this discussion could conceivably include:

HDTV video signal,
a number of SDTV video signals,
a number and variety of audio signals,
several concurrent data signals.

A type of HDTV terminal could be developed to utilize existing communications channels: DS-2, DS-3, ISDN, ATM, customized, etc. If such a channel were provided between two locations equipped with this type of terminal, all of the above transmission requirements between these locations could be satisfied with a single channel and terminal type. The type(s) of data to be transmitted over this channel would be at the discretion of the channel manager. The selection could be to transmit

data only up to the channel capacity,
share the channel capacity between voice and data,
voice, data, and video,
video and voice only.

Noting that data can include LAN or PC to PC communication, the channel becomes a true, highly flexible, multimedia channel with tremendous capability.

8. CONCLUSIONS AND RECOMMENDATIONS

8.1. Conclusion

A very definite conclusion was reached while gathering the material on HDTV and digital video communications: namely, that video communications, broadcast and private, is well on the way to converting from analog to digital. Many video teleconferencing systems and satellite video broadcast systems already operate in a digital transmission mode in accordance with existing standards. In fact, the Government may own many digital video systems. The transition pace will accelerate until, in the near future, all video communications will be digital. The advent of HDTV broadcasting will serve as the catalyst to foster the continued transition by enticing manufacturers to produce low cost HDTV and digital video equipment particularly in view of the fact that standards now exist to which to design such equipment. Home receivers, set top converters, digital video disks, digital video broadcast tape recorders, digital video cassette recorders, PC MPEG interface boards, digital cameras, and high resolution monitors. The digital video standards were developed to optimally utilize available and projected communications channels which will become available on a widespread basis.

8.2. Recommendations

It is important for the Government to assure that the HDTV and the international digital television standards and systems will provide the features the Government requires now or will require in the future. The standards define the television system infrastructure, conventions, syntax, formats, and the interoperability required of the system components. The features of the system will be defined, to a great extent, by the capabilities of the system components. Therefore, both standards and components are important to the overall capability which a system can provide to the Government.

Actual systems designed to the U.S. HDTV standard and the prototype components constituting these systems will soon be tested and evaluated extensively. The components to support these systems are presently being designed. The features of these components will be directed toward specific commercial markets. Features required for Government applications should be included in the component capabilities. The system components include display devices, video processing components, video storage devices, cameras, and maturing communications equipments and circuits.

The following steps are recommended to achieve this goal.

Follow the field testing of systems designed to the U.S. HDTV Standard and impact the direction of clarifications, capabilities, and enhancements which may be developed.

Continue following and impacting the development of the international digital television standards. These standards already provide a tremendous range of capabilities and are continuously expanding. As one example, there is a potential for modifying the ITU H.320 to include HDTV capability.

Follow and impact the development of hardware for HDTV systems and for other digital television systems to include capabilities required by the Government. Particular areas might include large scale video memories, enhanced communications capability, certain aspects of video processing, and, of course, improvements, simplifications, and cost reduction of compression components.

9. REFERENCE DOCUMENTS

The following is a compendium of very recent references to HDTV, digital TV, and the various essential items used to implement such systems. They contain the latest status of development in each category presented. The references are organized into three categories;

HDTV/Digital Standards,
Discussions and Explanation of the Standards, and
State-of-the-Art of Digital Equipment and Applications.

The list contains typical references for each of the above categories. Additional references can be obtained from those listed.

9.1. HDTV/Digital Standards

ATSC Draft Standard, "Digital Television Standard for HDTV Transmission" and all references therein.

ITU-T Recommendation H.310, "Broadband Audiovisual Communication Systems and Terminals", Draft, May 5, 1995.

ISO/IEC 13818-2/ITU Recommendation H.262, "Generic Coding of Moving Pictures and Associated Audio Information: Video", Draft International Standard, May 10, 1994.

9.2. Discussion and Explanation of Standards

Skran, Dale L., "ITU-T MultiMedia Telephony Standards H.320: for ISDN, ATM, PSTN", Presented at the 7th EIA Workshop on Digital Video, October 4, 1995. (ATT Bell Laboratories)

The Grand Alliance, "The U. S. HDTV Standard", IEEE Spectrum, April, 1995.

Robert Hopkins, PhD, " Overview of ATSC, HDTV, and SDTV Standards", Presented at the 7th EIA Workshop on Digital Video, October 6, 1995. (ATSC)

David Gillies, "DVB: The European Approach to Digital Video", Presented at the 7th EIA Workshop on Digital Video. (Thomson Consumer Electronics)

Walter Ciciora, "Cable Compatibility Status", Presented at the 7th EIA Workshop on Digital Video.

John F. Rice, "HDTV, The Politics, and Economics of Tomorrow's Television", Union Square Press, 1990.

EEE, Special Issue on Digital Television", Proc. IEEE, Vol. 83, No. 7, July 1995.

K. Challapali, et al, "The Grand Alliance System for US HDTV", Proc. IEEE, Vol 83, N,2, February 1995. (Phillips Laboratories, USA)

E. Petajan, "The HDTV Grand Alliance System", Proc. IEEE, Vol. 83, No. 7, July 1995. (ATT Bell Laboratories)

IEEE Spectrum, "The Digital Dawn in Europe", Special Issue Report on Digital Television, April 1995.

IEEE Spectrum, "The Japanese Scene", Special Issue Report on Digital Television, April 1995.

9.3. State-of-the-Art of Digital TV Equipment / Applications

Schaphorst, Richard " Videoconferencing Overview" September 22, 1995. (Delta Information Systems)

Thomas M. Gurley and Alan S Godber, "Grand Alliance System Test Results", Presented at the 7th EIA Workshop on Digital Video, October 6, 1995. (Advanced Television Test Center)

Joel Zdepski, "The Open TV Interactive TV System", Presented at the 7th EIA Workshop on Digital Video. (Thomson Sun Interactive Alliance)

Rob Goedman and Jim Kaubisch, "Video Servers and Surface Infrastructure", Presented at the 7th EIA Workshop on Digital Video. (Thomson MultiMedia)

K. Natarajan, "Video Servers Take Root", IEEE Spectrum 1995. (Hewlett-Packard)

Lauren Christopher, " Super Density Digital Video Disks", Presented at the 7th EIA Workshop on Digital Video. (Thomson R&D Labs)

Jack Fuhrer, "A Consumer Bit Stream Recorder for Digital Broadcast", Presented at the 7th EIA Workshop on Digital Video. (Hitachi America)

Steve Mahrer, "Digital Video Cassette", Presented at the 7th EIA Workshop on Digital Video. (Panasonic)

D.J. Mlynek, et al, "VLSI for Digital Television", Proc. IEEE, Vol. 83, No. 7, July 1995. (Swiss Federal Institute of Technology)

M. Umemoto, et al, "Digital Video Recording", Proc. IEEE, Vol. 83, No. 7, July 1995. (Network Systems Research Center, Hitachi)

D. E. Blahut, et al, "Interactive Television", Proc. IEEE, Vol. 83, No. 7, July 1995. (ATT Bell Laboratory)

Y. Ninomiya, "High Definition Television Systems", Proc. IEEE, Vol. 83, No. 7, July 1995. (Japan Broadcasting Corporation, NHK, Science and Technical Research Laboratories)

IEEE, Special Issue on Digital Television", Proc. IEEE, Vol. 83, No. 7, July 1995.

Hashimoto, et al, "Cameras and Display Systems", Proc. IEEE, Vol. 83, No. 7, July 1995. (Sony Corporation)

W. Ciciora, "Inside the Set-Top Box", IEEE Spectrum, April 1995.